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Highway Traffic Noise Prediction for Microcomputers

Modelling of Ontario Simplified Program

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Highway Traffic Noise Prediction for Microcomputers

Modelling of Ontario Simplified Program

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Abstract:	The U.S. FHWA highway traffic noise prediction model, STAMINA, published in 1977, has been used in many manual and computerized forms. This report presents a somewhat limited, but streamlined version of the model written in BASIC for use on personal computers and pocket computers. This version can be used to predict noise from highway traffic for many simple situations. The program predicts noise from three standard classes of vehicle at one receiver location, shielded by a barrier (of finite length). It includes the free field case, two parallel roadways, and is consistent with the assumptions made in STAMINA 2.0. The modelling and underlying assumptions are explained in sufficient detail to contribute to a better understanding of the STAMINA 2.0 mainframe program and the mathematical modelling in general.
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Modelling of Ontario Simplified Program

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1/ INTRODUCTION

The analytical method of traffic noise prediction known as STAMINA has been introduced in Ontario as a computer program for mainframe computers. In the mainframe environment, the STAMINA program can handle complex cases of noise control.

The underlying mathematical modelling was first published as a manual method in FHWA report RE-77-108, in 1978 [1]. This report was the basis for several simplified methods intended to be used for quick results in the course of planning activities, among them a nomographic method developed by the Ontario Ministry of Transportation and Communications (MTC) [2]. The proliferation of personal computers renders all purely manual methods (including the one presented in the FHWA report) obsolete. However, the modelling presented in the FHWA report is still relevant and valid.

Various attempts to simplify procedures and improve understanding of the modelling behind the STAMINA program were published in 1981 [3]. At that time, however, society was not fully geared to using personal computers. Now that personal computers are almost ubiquitous, it is appropriate to present the simplified STAMINA modelling concepts in a form suitable for programming microcomputers, leaving the mainframe programs for more complicated cases. The following concepts and improvements were developed based on the FHWA method [1, 3].

1/ Modified Subtending Angle -- The effect of ground absorption, as estimated and expressed by a coefficient, α, in free field segments, can be simply and fairly accurately incorporated by a modification of the subtending angles ϕ_1 and ϕ_2. This downward modification of both angles narrows the field segment and thus compensates for the effect of ground absorption. Calculating a modified subtending angle, $\bar{\phi} = \phi_1' - \phi_2'$, of a segment, the mathematical handling of the coefficient α becomes continuous and very simple (refer to Notation).

2/ Energy Level Equation -- Instead of adding up (logarithmic) decibel values, an equation has been developed which uses direct energy levels of (non-logarithmic) sound pressure energy. This not only assists in

simplifying computations with α, but also allows an additive treatment of vehicle traffic components, sometimes saving separate calculations for cars, and medium and heavy trucks.

3/ Curve Fitting of Basic Noise Attenuation Tables -- The noise attenuation tables in Reference 1, Appendix B, have been curve-fitted for $\phi_R = 90°$ and $\phi_L = -90°$, i.e., for the "infinitely" long barrier (minimum values) and for the very short segments (maximum values). Interpolation expressions have been derived to take care of a large range of tabulated Δ-values in Appendix B, Reference 1. Barrier segments, which are on one side and do not touch the receiver line perpendicular to the road axis, are not covered by the simplified method presented.

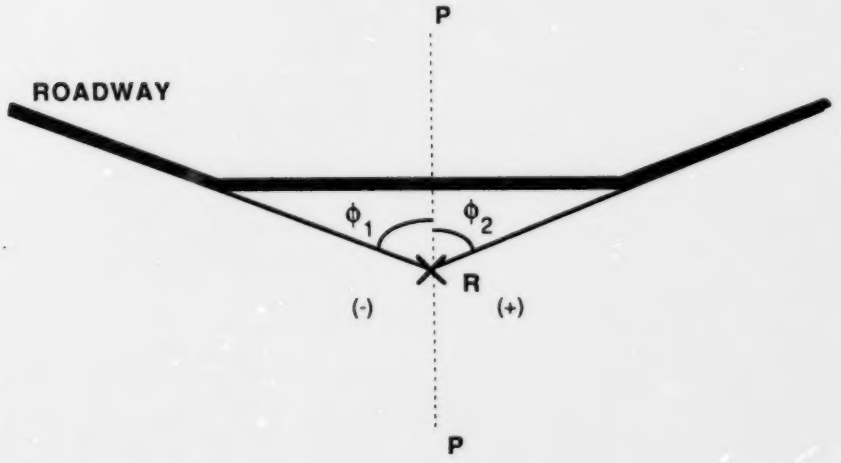

Figure 1/ Subtending Angle for "Turning Away" Roadway

2/ MODIFIED SUBTENDING ANGLE

The concept can be easily recognized from Equation A-6.4 on page A-29 of the FHWA report, Reference 1.

Looking from the receiver toward the roadway, the segment of investigation is enclosed by the angle ϕ_1 to the left and ϕ_2 to the right, as shown in Figure 1 for a special case of curving away roadway. They enclose the subtending angle, ϕ.

The subtending angle is always calculated as follows:

$$\phi = \phi_2 - \phi_1 \tag{1}$$

where ϕ_1 and ϕ_2 are measured from the line P-P perpendicular to the road, at the receiver position R, positive in the clockwise direction. Note that the angle, ϕ_1, in Figure 1 is negative.

In the case of soft, absorptive ground cover, the angles ϕ_1 and ϕ_2 are to be modified, and a modified or equivalent subtending angle is calculated as follows:

$$\bar{\phi} = \phi_2' - \phi_1' \tag{2}$$

The modified angles ϕ_1' and ϕ_2' have the same signs as the actual angles ϕ_1 and ϕ_2, respectively. The absolute values of ϕ_1 and ϕ_2 can be determined from Table 1, which is the solution of the following integral:

$$\phi_i' = \frac{180}{\pi} \int_0^{\phi_i} (\cos \phi)^{\alpha} \, d\phi \tag{3}$$

Substituting Equation 3 into Equation 2 leads to Equation A-6.4 of Reference 1, except for a factor of "180°".

In the computer program, the angles ϕ_1, ϕ_2, ϕ_1', ϕ_2', etc., are calculated from input values of distances and lengths of segments. In accordance with the convention on the sign of those angles, the lengths of segments,

or parts thereof, can be positive (to the right) or negative (to the left), refer to Figures 1 and 2.

Table 1/ Absolute Values of ϕ'

	$\alpha = 0$	$\alpha = 0.25$	$\alpha = 0.5$	$\alpha = 0.75$
0°	0	5.000	5.000	5.000
5°	5	4.998	4.997	4.995
10°	10	9.987	9.975	9.962
15°	15	14.957	14.914	14.872
20°	20	19.898	19.796	19.696
25°	25	24.799	24.601	24.406
30°	30	29.651	29.309	28.975
35°	35	34.442	33.901	33.374
40°	40	39.161	38.353	37.576
45°	45	43.793	42.645	41.554
50°	50	48.325	46.754	45.278
55°	55	52.741	50.654	48.723
60°	60	57.021	54.318	51.860
65°	65	61.141	57.714	54.659
70°	70	65.072	60.805	57.091
75°	75	68.772	63.544	59.119
80°	80	72.178	65.866	60.703
85°	85	75.173	67.664	61.785
90°	90	77.150	68.606	62.237

Note: For $\alpha = 1$ $\quad \phi' = \frac{180}{\pi} \sin \phi$ (4)

For algebraic expressions of $\phi' = f(\alpha)$ refer to Appendix A, Equations A-6.1, A-6.2 and A-6.3, in this report.

Values for the modified subtending angle, ϕ', can be taken from Table 1 for manual calculations.

Notation

V = total traffic on the road or on the part of the highway being considered, in vehicles per hour.

p = fraction of car traffic (subscript A in Reference 1); for instance, $p = 0.85$ means that cars represent 85% of V ($P = 85$).

q = fraction of medium truck traffic (subscript MT in Reference 1)

r = fraction of heavy truck traffic (subscript HT in Reference 1)

P,Q,R = percentage of car, medium truck, and heavy truck traffic, respectively

S = average traffic speed, in km/h, assumed to be uniform

D_o = reference distance from centreline of traffic, $D_o = 15$ m is the standard value

D_N = horizontal distance from the noise source to the centre of the nearest lane, in metres

D_F = horizontal distance from the noise source to the centre of the farthest lane, in metres

$D_E = \sqrt{D_N D_F}$ = equivalent lane distance, in metres (for free field only)

L = hourly reference energy emission level, in dBA

L_{eq} = equivalent sound level, in dBA

α = ground cover coefficient, according to the FHWA report [1]:
$\alpha = 0$ for hard, reflective surfaces
$\alpha = 0.5$ for soft, absorptive surfaces

ϕ = subtending segment angle in degrees, viewed from the point of the receiver towards the road

ϕ_1, ϕ_2 = subtending angles for a segment (see also FHWA report), refer to Figure 1.

ϕ_1', ϕ_2' = modified angles for a segment

$\bar{\phi}$ = equivalent subtending angle, $\bar{\phi}$ being reduced because of soft ground cover, refer to the following discussion

Δ = noise attenuation for a segment from a sound barrier parallel to the highway, in dBA

N_o = Fresnel number for path length difference δ

δ = path length difference perpendicular to the road axis, refer to Figure 6

I = sound barrier insertion loss, in dBA

For free field conditions, ground cover coefficients can be estimated in accordance with the following list:

Ground Cover Coefficients, α

$\alpha = 0$ reflective ground cover, such as paved parking lots, ice covered ground, collector and residential streets

$\alpha = 0.25$ moderately reflective ground cover, such as bare soil, minor patches of grass, partially paved back yards, parking lots interspersed with lawns

$\alpha = 0.5$ absorptive ground cover, such as lawns and soft soil fields, back yards with plants, flowers and small shrubs

$\alpha = 0.75$ very absorptive ground cover, such as back yards with trees and shrubs, corn fields, etc.

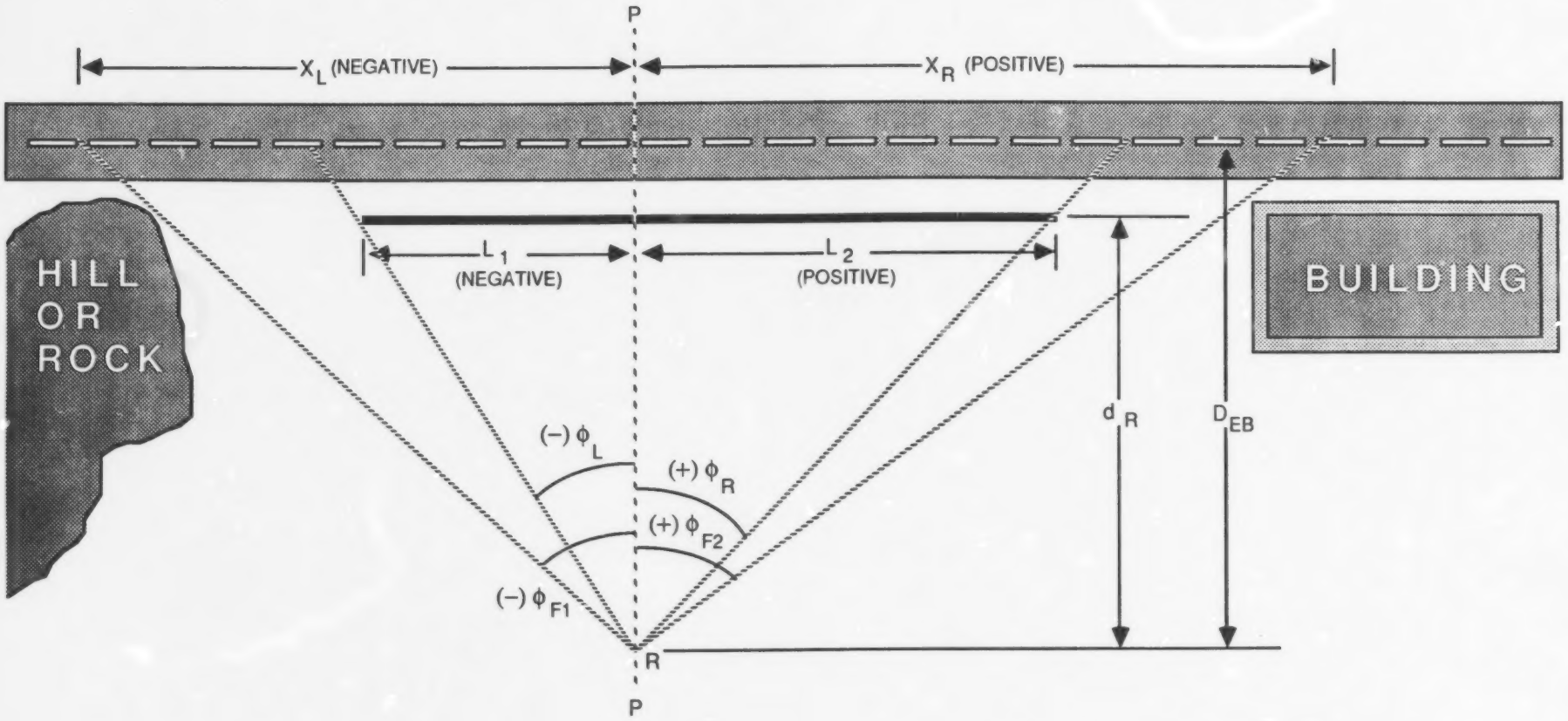

Figure 2/ Subtending Angles for Barrier and Roadway

X_L , X_R = Left and right road distances, or visible road length

L_1 , L_2 = Left and right barrier length

3/ ENERGY LEVEL EQUATION

The A-weighted reference energy mean emission level for cars, medium trucks, and heavy trucks can be transformed into direct energy expressions. The equations used in the original FHWA report are given on pages 4 and 5 of Reference 1. The transformed or "delogarithmized" equations are, for cars, medium trucks, and heavy trucks, respectively.

$$C = 0.57544 \cdot S_A^{3.81} \tag{5}$$

$$M = 43.6516 \cdot S_{MT}^{3.39} \tag{6}$$

$$H = 7079.4578 \cdot S_{HT}^{2.46} \tag{7}$$

This leads to a simple equation for the total hourly equivalent sound level, L_{eq} (h), in dBA:

$$L_{eq}(h) = 10 \log \left[\frac{\bar{\phi}}{15} \bar{VK} \left(\frac{15}{D_E} \right)^{1+\alpha} \right] \tag{8}$$

where: $$\bar{K} = K_A + K_{MT} + K_{HT} \tag{9}$$

$$K_A = (P/44253)\, S_A^{2.81} \tag{10}$$

$$K_{MT} = (Q/583.36)\, S_{MT}^{2.39} \tag{11}$$

$$K_{HT} = 0.27801 \cdot R \cdot S_{HT}^{1.46} \tag{12}$$

Equations 10, 11 and 12 (or A-3, A-4 and A-5) are derived from the original FHWA report, Reference 1. They represent national U.S. averages for vehicle types.

It is recommended that these equations be modified if vehicle noise emission levels differ from those established in the U.S. in 1977, although there is no reason to change the equations if differences are smaller than the statistical variations in the noise emission data.

The province of Ontario collected data in 1984 which resulted in a different set of equations:

$$K_A = (P/1114.14)\ S_A^{2.041} \qquad (10\text{-A})$$

$$K_{MT} = (Q/8.2402)\ S_{MT}^{1.406} \qquad (11\text{-A})$$

$$K_{HT} = 45.5051 \cdot R \cdot S^{0.259} \qquad (12\text{-A})$$

Equations B-1, B-2 and B-3 would replace Equations A-3, A-4 and A-5.

The underlying emission level equations can be found in Reference 6.

4/ BARRIER INSERTION

When free field noise is intolerably high, the insertion of a sound barrier wall may help. Figure 2 shows a typical case of a barrier which is shorter than the visible part of the roadway. There are three segments which contribute to traffic noise at Point R, namely left of the barrier, "over" the barrier, and right of the barrier. Their subtending angles are, respectively: $\phi_L - \phi_{F1}$, $\phi_R - \phi_L$, and $\phi_{F2} - \phi_R$. These angles can be calculated from length and distance dimensions which are also given in Figure 2. (Note that angles and corresponding barrier or roadway distances can be negative when pointing left from the perpendicular receiver line through R.) The three segments must be treated separately and their noise contributions added. The procedure is explained in the FHWA report [1]. Some of it is repeated in the following paragraph in order to establish references for programming.

The basic barrier attenuation, Δ, is a function of ϕ_L and ϕ_R, as defined in Figure 2, and of the Fresnel number, N_0.

The insertion of a barrier has an effect on sound absorption by a soft ground. For high barriers (4 to 5 m), the benefit of soft ground absorption can be assumed to be eliminated completely, so that such barrier sections must also be calculated for $\alpha = 0$. For barriers of low height (< 3 m) the absorption of a soft ground cover is still effective, but the coefficient α may be reduced considerably from its maximum value for the free field condition. Refer also to References 4 and 5.

Fresnel Number Calculation and Path Length Difference

This section is included to establish reference equations with respect to the PC program.

In the usual, well-known way, the Fresnel number is calculated as follows:

$$N_0 = 2\left(\frac{f\ \delta}{c}\right) = 2\left(\frac{550\ \delta}{343}\right) = 3.207\ \delta \cong 3.21\ \delta \qquad (13)$$

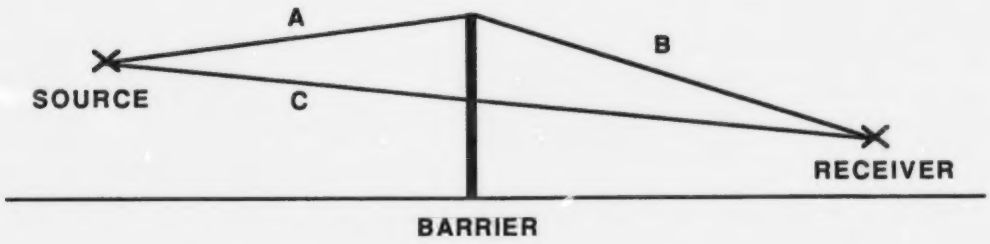

Figure 3/ Path Length Difference, δ

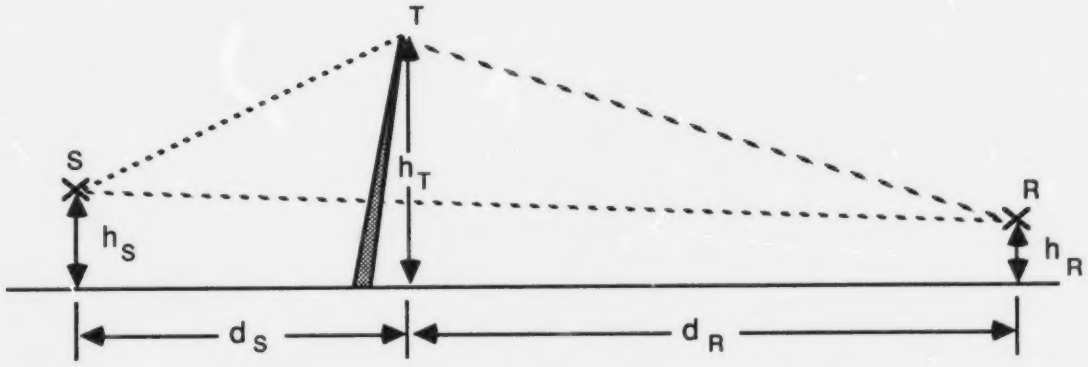

Figure 4/ Organizing the Calculation of δ

where: f = frequency of sound waves in Hz, f = 550 Hz is selected as a representative frequency for noise

c = velocity of sound in air = 343 m/s

δ = path length difference, in metres, between noise source and receiver, perpendicular to the road axis, comparing a direct path line C and an indirect path line over top of the barrier (A + B), refer to Figure 3, $\delta = A + B - C$.

To calculate the path length difference, one must organize the calculations in terms of horizontal distances and heights above the road surface. Denote in accordance with Figure 4.

h_S = level of noise source above the road surface, in metres

h_R = level of receiver of noise above the road surface, in metres

h_T = level of barrier top above the road surface, in metres

d_S = horizontal distance of noise source from a vertical plane through the barrier top, in metres

d_R = horizontal distance of receiver from a vertical plane through the barrier top, in metres

Then:

$$\delta = A + B - C \tag{14}$$

$$\delta = \sqrt{(h_T - h_S)^2 + d_S^2} + \sqrt{(h_T - h_R)^2 + d_R^2} - \sqrt{(h_S - h_R)^2 + (d_S + d_R)^2}$$

The following assumptions are made for receiver and source heights above ground or road surfaces, respectively:

Noise from cars:	$h_{SA} = 0$
from medium trucks:	$h_{SMT} = .7$ m
from heavy trucks:	$h_{SHT} = 2.44$ m
Receiver above ground: (may be lower or higher than 1.5 m above the road surface)	$h_R = 1.5$ m

Once a barrier is in place, the equivalent lane distance from the source to the receiver is different. Denote:

d_N = distance of near lane from barrier, in metres

d_F = distance of far lane from barrier, in metres

Then: $$D_{EB} = d_R + \sqrt{d_N \times d_F} \qquad (15)$$

5/ CALCULATING BARRIER ATTENUATION

Basic Equations

The original FHWA report [1] presents the solution of a complex integral in the form of tables for the value Δ, the noise attenuation in dBA, representing a function of N_0, ϕ_L, and ϕ_R, given on pages B-11 to B-71 of Reference 1. The important range is from $N_0 = 0.05$ for $N = 3$. Beyond this range, the barrier would either not be warranted or it would be too high (5 m or higher), heavy and ugly. High barriers with $N_0 > 3$ are still included, and low barriers, below $N_0 = 0.05$ approach a value of $\Delta = 5$dB without much error or deviation.

A portion of the aforementioned tabulated function has been curve-fitted. The basis of this approach was established by finding an equation for the values of Δ, for $\phi_L = -90°$ and $\phi_R = +90°$ (i.e., for an infinitely long barrier). This equation is a function of N_0 only:

$$\Delta_I = 5 + 14.4 \cdot e^{-0.175(2 - \log N_0)^{2.5}} \qquad (16)$$

The equation is accurate within ± 0.04 dB, i.e., it is as accurate as the table values.

Equation 16 is only valid for barriers which intercept the line of sight between source and receiver. For barriers with a top lower than this line of sight, the following equation is assumed, using positive values of N_0 as input.

$$\Delta = 5 - 25\ N_0 > 0 \qquad (17)$$

Equation 17 is an assumed approximate modelling for this range of low barrier heights where accuracy is of lesser importance.

Because of the limitations in the calculation of barrier attenuation values, cases where the barrier height above the roadway surface is less than 0.6 m (2 feet) should be declared invalid. (Cases below 2 m height should be approached with some caution when the ground cover is soft.)

The maximum values of Δ for short segments of barriers at the source-receiver line, given on pages B-11 to B-71 of Reference 1, have also been curve-fitted as follows:

$$\Delta_{max} = 5.15 + 14.4\ e^{-0.59(1-\log N_0)^2} \tag{18}$$

Between these Δ-values, for infinitely long and very short barriers (Δ_I and Δ_{max}), a complex interpolation formula has been derived as follows:

$$\Delta = \Delta_{max} - (\Delta_{max} - \Delta_I)(\phi_E/90)^{\eta} \tag{19}$$

where:

$$\phi_E = \frac{\phi_R - \phi_L}{2} \qquad \text{(average of } |\phi_R| \text{ and } |\phi_L|) \tag{20}$$

$$\eta = 1 + \left(1.25 + \frac{N_0}{2}\right)\left[1 - 3.24\left(\left|\frac{\phi_L + \phi_R}{90}\right|\right)^2\right] \tag{21}$$

This interpolation is valid for a certain limit of the difference between $|\phi_R|$ and $|\phi_L|$, namely for:

$$\phi_R + \phi_L < 45° \qquad \text{(note, } \phi_L \text{ is negative)} \tag{22}$$

For differences outside this domain, $\phi_R + \phi_L > 45°$, the following approximation is more accurate than Equations 20 and 21:

$$\eta = 1 + \left(1.25 + \frac{N_0}{2}\right)$$

$$\phi_E = \phi_R + \frac{\phi_L}{5} \qquad \text{for } |\phi_R| > |\phi_L|$$

$$\phi_E = -\phi_L - \frac{\phi_R}{5} \qquad \text{for } |\phi_L| > |\phi_R|$$

Normally, ϕ_R is always positive and ϕ_L is always negative, according to definitions given in Figures 1 and 2, or in Chapter 2. However, small angles of opposite sign (up to 10°) can be accepted. Thus, the following condition was introduced:

If $\phi_R < -10°$ or $\phi_L > +10°$, the barrier insertion loss is declared invalid.

Ground Absorption

With regard to the selection of a ground absorption coefficient, α, the following comments should be noted.

When the ground cover coefficient, α_F, for free field sound absorption is selected in accordance with the list presented on Page 6, the program user should understand that the recommended values are only for normal, fairly even terrain. For the beneficial effect of ground absorption, i.e. the coefficient, α, deteriorates when the level of the sound propagation paths between source and receiver above the absorptive ground increases beyond the normal average height of source and receiver. This condition is given for high noise barriers, but also when the ground between source and receiver is significantly depressed.

In the STAMINA 2.0 mainframe computer program the value, α_B (for barrier present) is therefore set zero in any segment where a barrier is present, before the attenuation, Δ, is deducted (refer to the terms LB and Δ in Equation 21). Generally, this results in a much reduced or decreased "net" insertion loss (compared to Δ). For very low barrier heights this could even lead to "negative" values of such a net insertion loss, which would actually be an apparent gain in noise level above the level under force field conditions, in spite of the presence of a barrier. The program avoids such embarrassing contradictions by internal controls (IF THEN LL = LF), without having a true solution.

When a valley or a ground depression of some kind is located between the source and receiver, the coefficient, α_F, should be selected accordingly, i.e., below the pertinent value indicated in the list on page 6. A further reduction from α_F to α_B is then less severe.

For barriers of low and moderate height (below 3 m) there is a transition problem in so far as the value α_F, and zero. For more guidance on this issue, the reader is referred to Reference 5. Without this precaution, both programs (the PC versions presented here) and the mainframe STAMINA would underestimate the effect of low-height barriers in a terrain of absorptive ground. The problem of ground absorption however, is not sufficiently clarified to recommend a definite procedure in this matter.

6/ CALCULATION PROCEDURES

Calculations are carried out for the three vehicle types (cars, medium trucks, and heavy trucks) and for a maximum of two parallel roadways separately, and the results are then combined or added at a later stage.

The program consists of one basic subroutine to calculate the free field noise for any segment, using "dummy" variables for D_E, α, ϕ_1, ϕ_2, the angles left and right of the segment, measured clockwise from the perpendicular line through point R (i.e., the line P-P in Figures 1 and 2).

Using this subroutine, free field noise levels are calculated from the total roadway section (LF) from ϕ_{F1} to ϕ_{F2}, the barrier section (LB) from ϕ_L to ϕ_R, the segment left of the barrier (LX) from ϕ_{F1} to ϕ_L, and the segment right of the barrier (LY) from ϕ_R to ϕ_{F2}, refer to Figure 2.

Another major part of the program consists of calculating barrier attenuation, denoted as Δ, for each vehicle type, and for the segment with barrier, from ϕ_L to ϕ_R, adjusted in accordance with the method shown above. The barrier net insertion loss (IL) for each vehicle type and for roadway is then calculated as,

$$IL = LF - \underbrace{(LB - \Delta + LX + LY)}_{\text{noise level after barrier construction (LL)}} \qquad (21)$$

At the end, the two kinds of noise levels, (LF) and (LL), for each roadway are then added to totals of (LF) and (LL). A new, final net insertion loss is then calculated (as I = LF - LL).

The sound absorption coefficient α_F for ground cover, as listed earlier, is only valid for free field conditions (LF, LX, LY). The term LB must be calculated with a reduced α, and the STAMINA mainframe computer program assumes a value of $\alpha_B = 0$, which may be too low for very low barrier heights, refer to Reference 5. To be consistent with STAMINA, the program here assumes $\alpha_B = 0$ unless another option is chosen.

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Appendix A/

A Simple Set of Equations for Programming Personal or Pocket Computers

Free Field Noise Prediction

Based on actual FHWA equations for vehicle emission levels.

$$L_{eq} = 10 \log \left[\frac{\bar{\phi}}{15} \; V \; \bar{K} \left(\frac{15}{D_E}\right)^{1+\alpha}\right] \qquad \text{(A-1)}$$

where:

$D_E = \sqrt{D_N \; D_F}$ = equivalent lane distance for free field, in metres

$$\bar{K} = \bar{K}_A + \bar{K}_{MT} + \bar{K}_{HT} \qquad \text{(A-2)}$$

$$\bar{K}_A = (p/44253) \times S_A^{2.81} \qquad \text{(cars)} \qquad \text{(A-3)}$$

$$\bar{K}_{MT} = (Q/583.36) \times S_{MT}^{2.39} \qquad \text{(medium trucks)} \qquad \text{(A-4)}$$

$$\bar{K}_{HT} = .27801 \times R \; S_{HT}^{1.46} \qquad \text{(heavy trucks)} \qquad \text{(A-5)}$$

S_A = car speed, in km/h

Also refer to page 6.

S_{MT} = medium truck speed, in km/h

S_{HT} = heavy truck speed, in km/h

where $\bar{\phi} = \phi_2' - \phi_1'$, as discussed previously, see Table 1.

$$\phi_i' = \phi_i \left[1 - \frac{M}{|\phi_i|} \left(\frac{|\phi_i|}{90}\right)^n\right] \qquad \text{(A-6.1)*}$$

---

* Approximation for Table 1 values; deviation < 0.8%.

$$M = (90)\left(\frac{0.58\,\alpha^{0.9}}{0.58\,\alpha^{0.9} + 1}\right) \qquad \text{(A-6.2)}$$

$$n = \frac{1}{0.134\alpha + 0.225} \qquad \text{(A-6.3)}$$

For $\alpha = 1$, the accurate solution is:

$$\bar{\phi} = \frac{180}{\pi}(\sin \phi_2 - \sin \phi_1) \qquad \text{(A-7)}$$

The special case of $\phi_2 = 90°$ and $\phi_1 = -90°$ has been approximated by a different equation:

For $0 < \alpha < 0.75$,

$$\bar{\phi} = \frac{180}{1 + 0.58\,\alpha^{0.9}} \qquad \text{(A-8)}$$

For $\alpha = 1$, the accurate solution is:

$$\bar{\phi} = \frac{180}{\pi/2} \qquad \text{(A-9)}$$

The ground cover coefficient is treated as a continuous variable. The approximation of the integral Equation 3, represented by Equations A-6.1, A-6.2, and A6.3, is accurate enough for all practical purposes.

Noise Barrier Attenuation

Presented below is an approximate, curve-fitted solution of the integrals, as represented in Figure A-1.

For an "infinitely" long barrier, i.e., for $\phi = 180°$, or for barrier sections of $\phi = \phi_2 - \phi_1 = 90°$, left or right from the perpendicular line through the receiver location, the sound barrier attenuation can be calculated approximately by:

$$\Delta_I = 5 + 14.4\, e^{-0.175(2-\log N_0)^{2.5}} \qquad \text{(A-10)}$$

where: $$N_0 = \frac{f\delta}{171.5^*} \qquad \text{(A-11)}$$

$$\delta = \sqrt{(h_T - h_S)^2 + d_S^2} + \sqrt{(h_T - h_R)^2 + d_R^2} - \sqrt{(h_S - h_R)^2 + (d_S + d_R)^2} \qquad \text{(A-12)}$$

For h- and d- values refer to Figure 4.

The equivalent lane distance when barrier is present in the segment is:

$$D_{EB} = d_R + \sqrt{d_{NB} \cdot d_{FB}} \qquad \text{(A-13)}$$

where d_{NB} and d_{FB} are the near and far distances of the source from the barrier.

For sound barriers which are finite, adjustments must be made to the basic value of Δ calculated from Equations A-10 and A-11. For this purpose, the maximum values for short segments of barriers, Δ_{max}, have also been curve-fitted, and interpolation formulae have been derived (refer to Chapter 5).

---

* Note: 171.5 is half the speed of sound waves in air, in m/s.

Appendix B/

Low Level "BASIC" Program

Appendix B/ Low Level "BASIC' Program

1/ Printout of Program

```
10      REM BARRIER NOISE PREDICTION PROGRAM
15      DIM LU(4), LV(4) : OPEN 4,4,0
20      READ V, Q, R, S1, S2, S3
25      READ NR, X1, X2, DN, DF, AF
30      LET P = 100-R-Q : DO = SQR(DN*DF)
40      LET PI = 3.14159265 : X = 180/PI
45      F1 = X*ATN(X1/DO) : F2 = X*ATN(X2/DO)
50      D1 = DN-DR : D2 = DR-DR
55      DS = SQR(D1*D2) : DB = DR + DS
60      FL = X*ATN(L1/DR) : FR = X*ATN(L2/DR)
65      IF FL < F1 THEN FL = F1
70      IF FR > F2 THEN FR = F2
75      DEF FN F(XX) = INT(1000*XX +.5)/1000
80      INPUT "ALPHA FOR BARRIER FIELD = ";AB
85      GOTTO 350
90      REM FREE FIELD NOISE SUBROUTINE
100     IF AL=0 THEN PH=P2-P1 : GOTO 230
110     IF ALL=1 THEN PH = (SIN(P2/X)-SIN(P1/X)*X : GOTO 230
130     N = 1/(0.1334*AL + 0.225)
140     M = (90)*(0.58*AL↑ 0.9 + 1)
150     Y1 = ABS(P1) : Y2 = ABS(P2)
160     IF P1 = 0 THEN GOTO 180
170     PA = P1*(1-(M/Y1)*(Y1/90.)↑ N)
180     IF P2 = 0 THEN GOTO 200
190     PB = P2*(1 -(M/Y2)*(Y2/90.)↑ N)
200     IF P1 = 0 THEN LET PA = 0
210     IF P2 = 0 THEN LET PB = 0
220     PH = PB - PA
230     K(1) = (P/44253)*S1↑ 2.81
240     K(2) = (Q/583.36)*S2 ↑ 2.39
250     K(3) = 0.27801*R*S3 ↑ 1.46
260     K(4) = K(1) + K(2) + K(3)
270     FOR J = 1 TO 4 STEP 1
280     IF PH < 0.001 THEN L(J) = 0
290     IF PH < 0.001 GOTO 330
300     IF K(J) = 0 THEN L(J) = 0
310     IF K(J) = 0 GOTO 330
320     L(J) = (10/LOG(10))*LOG((PH/15)*V*K(J)*(15/DE) ↑ (1+AL))
330     NEXT J
340     RETURN
350     REM FREE FIELD NOISE FOR C, MT, HT
360     P1 = F1 : P2 = F2 : AL=AF : DE=D0
370     GOSUB 100
380     FOR J = 1 TO 4 STEP 1
390     LF(J) = L(J)
400     U(J) = FN F(LF(J))
410     NEXT J
420     PRINT U(1), U(2), U(3), U(4)
440     IF A=1 GOTO 810
450     REM FR. FIELDLNOISE OF BARRIER SEC.
460     P1 = FL : P2 = AL = AB : DE = DB
470     GOSUB 100
480     FOR J = 1 TO 4 STEP 1
490     LB(J) = L(J) : NEXT J
```

In this part of the program (15 to 80) basic values are calculated and stored, i.e. input is read, equivalent lane distances calculated (D0, DB), free field (F1, F2) and barrier field angles (FL, FR) are computed and checked for consistency; finally, an output function for the rounding to three decimal places is defined.

This is the basic subroutine for insertion-free calculation of noise levels in a particular field from ϕ_1 to ϕ_2. First, modified subtending angles are calculated $\phi_1 \rightarrow \phi_1'$ (P.1 $\rightarrow$PA) and $\phi_2 \rightarrow \phi_2'$ (P2 $\rightarrow$PB) in accordance with Appendix A. Then actual energy levels for cars, medium trucks, heavy trucks, and total are calculated (K(J), J=1 to 4). The decibel level is calculated in 320. Input dummy variables are, P1, P2, AL, DE, for ϕ_1 ϕ_2, α, d_E, respectively.

Free field noise for the condition before constructing a barrier is calculated. Results are stored in LF(J) (accurate) and U(J) (Rounded).

"Free field" noise of barrier section without barrier but with reduced α is calculated, stored in LB(J) (accurate).

```
500   REM CALCULATE DELTAS OF BARRIER
510   LET H(1) = 0.0
520   LET H(2) = 0.7
530   LET H(3) = 2.44
540   FOR J = 1 TO 3 STEP 1
550   AA = SQR((HB-H(J))*(HB-H(J)) + DS* DS)
560   BB = SQR((HB-HR)*(HB-HR + DR*DR)
570   CC = SQR ((H(J)-HR)*(H(J)-HR) + DB*DB)
580   PD(J) = AA + BB - CC
590   T(J) = 3.207 * PD(J)
600   NEXT J
610   GOSUB 1000
615   IF A = 1 GOTO 810
620   FOR J = 1 TO 3 STEP 1
630   LG = LOG(T(J))/LOG(10)
640   DY = 5 + 14.4*EXP(-.175*(2-LG)↑ 2.5)
650   DX = 5.15 + 14.4*EXP(-.59*(1-LG ↑ 2)
660   IF NN > 1.0 THEN NN = 1
670   IF NN < 6.0 THEN NN = 6.0
720   D(J) = DX-(DX-D6)*(FI/90) ↑ NN
730   IF D(J) > 19.5 THEN D(J) = 19.5
```

In accordance with Chapter 5, a streamlined modelling, the path length difference is calculated, PD(J), for cars, medium, and heavy trucks, then Fresnel No. , T(J) and, finally, the basic barrier insertion loss, D(J), in accordance with an improvd model. For "line of sight" receivers, 740 gives a simple modelling of a small, conservative value. This calculation of D(J) in general is based on an entrance value, FI, which is an effective subtending angle, ϕ_E established in subroutine 1000. D(J) is calculated by a complex interpolation between a maximum (DX) and a minimum value (DY),

```
740   IF HB-HR ≤ (H(J) -HR)*(DR/DB) THEN D(J) = 5 - 25*T(J)
745   IF D(J) 0 THEN D(J) = 0
750   V(J) = FN F(D(J))
755   NEXT J : AR = 0
760   PRINT V(1), V(2), V(3)
770   FOR J = 1 TO 3 STEP 1
780   LL(J) = LB(J)-D(J)
785   W(J) = FN F(LL(J))
790   AR = AR + 10 ↑ (LL(J)/10) : NEXT J
800   LL(4) = 10*(LOG(AR))/LOG(10)
802   W(4) = FN F(LL(4))
805   PRINT W(1), W(2), W(3), W(4)
810   REM FREE F. NOISE & DELTA OUTPUT
820   PRINT#4, "    FREE FIELD NOISE LEVEL AND DELTA VALUES"
830   PRINT#4
840   PRINT#4,"CARS:      ",U(1),V(1)
850   PRINT#4, "MEDIUM TRUCKS:  ",U(2), V(2)
860   PRINT#4,"HEAVY TRUCKS: ",U(3),V(3)
870   PRINT#4,"TOTAL, ALL VH.:,U(4)
875   IF A = 1 THEN PRINT#4,"INVALID BARRIER CASE"
876   IF A=1 THEN PRINT "INVALID BARRIER CASE"
877   IF A=1 GOTO 2200
880   PRINT#4 : PRINT#4
885   IF FI > 89 GOTO 1890
890   IF FL < = -88 GOTO 915
895   P1 = F1 : P2 = FL : AL = AF : DE = D0
900   GOSUB 100
905   FOR J = 1 TO 4
910   LX(J) = L(J) : NEXT J
915   IF FR > = 88 GOTO 940
920   P1 = FR : P2 = F2 : AL = AF : DE = DO
925   GOSUB 100
930   FOR J = 1 TO 4
935   LY(J) = L(J) : NEXT J
940   FOR J = 1 TO 4
```

A preliminary value, LL(J), of individual (J=1,2,3) and total(J=4) net insertion loss is calculated, accurately stored in LL(J), and rounded in W(J) .

Rounded values of D(J) are stored in V(J).

Rounded values of free field noise, U(J) and of basic insertion losses, V(J), are printed.

In this part of the program the "leakages" (if any) around the ends of the barrier are calculated, which have to be added to LL(J), namely LX(J) at the left side and LY (J) at the right side.

This addition of LX and LY to LL is carried out here (940 to 960), and a new, augmented LL(J) replaces the preliminary one.

```
945   KK = 10 ↑ ((LL(J))/10 + 10 ↑ ((LX(J))/10) + 10 ↑ ((LY(J))/10)
950   LL(J) = 10*LOG(KK)/(LOG(10))
955   IF LL(J)  LF(J) THEN LL(J) = LF(J)
960   W(J) = FN F(LL(J))
965   NEXT J
970   PRINT W(1), W(2), W(3), W(4)
975   GOTO 1800
1000  REM SUBROUTINE DETERMINING FI & NN
1005  LET QQ = 0.20
1010  IF FR < -10 GOTO 1060
1015  IF FL > +10 GOTOT 1060
1020  IF ABS(FR+FL) ≤ 45 GOTO 1100
1030  IF ABS(FR) > ABS(FL) GOTTO 1120
1040  IF ABS(FR) < ABS(FL) GOTO 1130
1060  A = 1 : GOTO 1150
1100  NN = 1+(1.25+ T(J)/2) *(1-3.24*(ABS(FR+FL)/90 ↑ 2)
1110  FI = (FR - FL)/2 : GOTO 1150
1120  FI = FR + QQ*FL
1125  NN = 2.25 + T(J)/2 : GOTO 1150
1130  FI = -QQ*FR - FL
1135  NN = 2.25 + T(J)/2
1150  RETURN
```

This subroutine calculates an effective subtending angle, FI, (ϕ), which, after return to 610, leads to a proper basic insertion loss. The concept is to calculate an effective "average" FI as it differs from 90° and leads to a suitable modification in 720. The result is checked against restrictions (1010 and 1015).

```
1890  FOR J = 1 TO 4 STEP 1
1900  IL(J) = LF(J) - LL(J)
1905  Z(J) = FN F(IL(J)) : NEXT J
1910  REM FINAL OUTPUT FOR ONE ROADWAY
1915  PRINT Z(1), Z(2) , Z(3), Z(4)
1920  PRINT#4,"  NOISE AFTER BARRIER AND NET INSERTION LOSS:
1930  PRINT#4
1940  PRINT#4,"CARS:   ",W(1),Z(1)
1950  PRINT#4,"MEDIUM TRUCKS:",W(2),Z(2)
1960  PRINT#4,"HEAVY TRUCKS:  ",W(3),Z(3)
1970  PRINT#4,"TOTAL,ALL VH. :  ",W(4),Z(4)
1980  PRINT#4 : PRINT#4
```

Here , the final net insertion losses are calculated and stored accurately in IL(*J*), and rounded in Z(J).

Final noise levels (W) and net insertion losses (Z) are printed as round values to three decimal places, for one roadway.

```
1985  IF LU(4) <> 0 GOTO 2060
1990  ON NR GOTO 220O, 2000
2000  REM STORE IMPORTANT RESULTS
2010  FOR J = 1 TO 4
2020  LU(J) = LF(J) : LV(J) = LL(J)
2030  NEXT J
2040  GOSUB 2210      — New input for second roadway.
2045  GOTO 35         — Repeat calculation for second roadway.
2060  FOR J = 1 TO 4
2070  SS = 10 ↑ (LU(J)/10)+10 ↑ (LF(J)/10)
2080  FF(J) = (10/LOG(10))*LOG(SS)
2085  XU(J) = FN F(FF(J))
2090  RR = 10 ↑ (LLV(J)/10) +10 ↑ (LL(J)/10)
2100  YY(J) = (10/LOG(10))*LOG(RR)
2105  YV(J) = FN F(YY(J))
2110  II(J) = FF(J) - YY(J)
2115  IW(J) = FN F(II(J))
2130  NEXT J : PRINT#4 : PRINT#4
2140  PRINT#4,"TOTALS FROM TWO ROADWAYS:
2150  PRINT#4 : PRINT
2155  PRINT#4,  "NO." ," BEFORE"," AFTER","  INS.LOSS"
2160  FOR J = 1 TO 4
```

The program checks whether or not a second roadway has already been calculated; if not, then LU(4) must be zero. If yes, then control switches to 2060.

If there is not a second roadway, the program must go to the end. In case of a second roadway NR=2, noise levels LF(J) and LL(J) must be temporarily stored in LU(J) and LV(J), respectively.

The results for both roadways are combined. Note that the results of the first roadway are in LU(J) and LV(J), whereas the results of the second roadway are now in LF(J) and LL(J). From the combined values, the final net insertion losses can be calculated: IL(J), IW(J) rounded.

```
2170    PRINT XU(J), YLV(J),  IW(J)
2180    PRINT#4, J, XU(J), YV(J), IW(J)
2190    NEXT J : PRINT#4
2200    CLOSE 4: END
```

Printing of final results for two roadways, and end.

```
2210    REM READING NEW DATA FOR SECOND ROADWAY
2220    READJ V, Q, R, S1, S2 S3
2230    READ X1, X2, DN, DF, AF
2240    RETURN
```

In this subroutine new data for the second roadway are read into memory.

```
3000    REM
3010    REM   V, Q, R, S1, S2, S3
3020    DATA 363, 6.612, 6.061, 75, 75, 75
3030    REM
3040    REM NR, X1, X2, DN, DF, AF
3050    DATA 2, -10000, 10000, 60, 60, .50
3060    REM
3070    REM HB, L1, L2, DR, HR, RS
3080    DATA 1.5, -500.0, 500.0, 48.17, 1.5, 1.5
3090    REM
```

Basic data for the first roadway.

```
3100    REM
3110    REM   V, Q, R, S1, S2, S3
3120    DATA 318, 3.774, 7.862, 75, 75, 75
3130    REM
3140    REM  X1, X2, DN, DF, AF
3150    DATA -100000, 10000, 63.66, 63.66, .5
```

Additional data for the second roadway, read in 2220.

As an example, refer to Appendix D with similar input, except for HB = 4.0 m L1 = -17.532 m L2 = 132.346 m
(example from Reference 1)

2.1 Notation

Input Terms

NR = Number of roadways, one (1) or two (2).

X1 = Length of visible roadway, in metres, to the left of the perpendicular receiver line, must be a negative value when measured to the left of that line. (Exception: skew to the right).

X2 = Length of visible roadway, in metres, to the right of the perpendicular receiver line; must be a positive value when measured to the right of the line. (Exception: skew to the left).

DN = Near lane distance from receiver, in metres.

DF = Far lane distance from receiver, in metres.

AF = Ground absorption coefficient (α) for free field, to be chosen according to ground cover conditions.

AB = Modified ground absorption coefficient for a field after barrier insertion; for barrier of normal height this value is equal to zero.

HB = Barrier height measured from roadway surface level, in metres.

L1 = Length of the barrier left of the perpendicular receiver line, must be negative when measured to the left of that line; in metres.

L2 = Length of the barrier right of the perpendicular receiver line, must be positive when measured to the right of that line, in metres.

DR = Distance between receiver and barrier, in metres, measured perpendicular to the road axis.

HR = Receiver height above the road surface level, in metres, can be positive or negative, depending on the ground level at the receiver. (The standard assumption is 1.5 m above ground level, then add the difference between ground and roadway level).

RS = Standard reciever height above ground level, in metres (1.2 m or 1.5 m).

V = Hourly volume of total traffic, number of vehicles (cars and trucks) per hour.

P = Percentage of automobiles or cars and small trucks.

Q = Percentage of medium trucks.

R = Percentage of heavy trucks.

Calculated Terms

F1, F2 = Subtending angles calculated from X1 and X2. ***Note:*** *that F1 and FL are usually negative values; all angles in degrees.*

FL, FR = Subtending angles calculated from L1 and L2.

DO = Equivalent lane distance, in metres, for free field condition.

DB = Equivalent lane distance, in metres, for field with barrier insertion.

input "dummy" variables for a section or segment

P1 = left subtending angle

P2 = right subtending angle

AL = ground cover coefficient, α

DE = equivalent lane distance in metres

PA = Modified subtending angle, in degrees, to the left of the segment, (ϕ_1').

PB = Modified subtending angle, in degrees, to the right of the segment, (ϕ_2').

PH = PB - PA, = $\bar{\phi}$

L(J) = Noise level, dBA, output "dummy" variable.

LF(J) = Noise level, in dBA, for freefield, before barrier.

LB(J) = Noise level, in dBA, for barrier field or segment.

LL(J) = Noise level, in dBA, after barrier construction.

H(J) = Source heights, in metres, for cars, medium and heavy trucks.

PD(J) = Path length differences, in metres.

T(J) = Fresnel number (N_0) .

D(J) = Noise attenuation (Δ), basic values, in dB.

FI, FF = Entrance angle, in degrees, for modifying the noise attenuation value, D(J).

LX(J) = Leakage of noise left of the barrier, in dBA.

LY(J) = Leakage of noise right of the barrier, in dBA.

IL(J) = Net insertion loss, in dBA, for one roadway.

FF(J) = Free field noise level, in dBA, from two roadways.

YY(J) = Noise level after barrier installation, from two roadways.

II(J) = Final net insertion loss for two roadways.

The arrays defined above have different names for the values rounded to three decimal places. For practical application, a further rounding to one decimal place is recommended.

Deviations from STAMINA are predominantly conservative, ranging from 1/10 to 1/3 dBA (approx.). The larger errors occur for larger values of D(J). Deviations for free field noise calculations are less than 1/10 dBA.

Appendix C/

High Level "BASIC" Program

```
10 REM  ************************************************************************
20 REM             HIGHWAY NOISE PREDICTION METHOD
30 REM ************************************************************************
40 KEY OFF:SCREEN 1:COLOR 0,2
50 CLS:BLOAD"a:stamlogo
60 T$=INPUT$(1)
70 SCREEN 2:SCREEN 0:COLOR 10
80 LOCATE 2,27:PRINT "M  A  I  N     M  E  N  U"
90 LOCATE 3,27:PRINT STRING$(25,22):COLOR 15:QQ=0
100 FOR I=5 TO 19 STEP 2
110 QQ=QQ+1
120 LOCATE I,21:PRINT "[";QQ;"]":NEXT I
130 COLOR 7:LOCATE 5,28:PRINT"Load a Previously Saved Data Set"
140 LOCATE 7,28:PRINT"Enter New Input Data"
150 LOCATE 9,28:PRINT"Review Input Data"
160 LOCATE 11,28:PRINT"Edit Road Input Data"
170 LOCATE 13,28:PRINT"Calculate Sound Levels"
180 LOCATE 15,28:PRINT"Save the Input Data for Later Use"
190 LOCATE 17,28:PRINT"Add Sound Levels"
200 LOCATE 19,28:PRINT"EXIT PROGRAM
210 LOCATE 4,18:COLOR 4:PRINT STRING$(1,201):LOCATE 4,19:PRINT STRING$(43,205):L
OCATE 4,62:PRINT STRING$(1,187)
220 LOCATE 20,18:PRINT STRING$(1,200):LOCATE 20,19:PRINT STRING$(43,205):LOCATE
20,62:PRINT STRING$(1,188)
230 FOR I=5 TO 19
240 LOCATE I,18:PRINT STRING$(1,186):LOCATE I,62:PRINT STRING$(1,186):NEXT I
250 LOCATE 22,28:COLOR 15:PRINT "SELECT AN OPTION"
260 LOCATE 21,24,0:COLOR 20:PRINT STRING$(1,179):LOCATE 22,24:PRINT STRING$(1,19
2):LOCATE 22,25:PRINT STRING$(2,196)
270 A$=INPUT$(1):IN1=VAL(A$):CLS:COLOR 7
280 IF IN1>=3 AND NR =0 THEN GOTO 290 ELSE GOTO 300
290 IF IN1<=6 AND NR =0 THEN GOTO 70
300 SCREEN 0,80:ON IN1 GOSUB 3790,450,1040,3090,1380,3790,4660,320
310 GOTO 70
320 LOCATE 10,25:COLOR 7:PRINT"[B]  Exit to BASIC operating system"
330 LOCATE 12,25:PRINT"[D]  Exit to DISK operating system (DOS)"
340 LOCATE 14,25:PRINT"[Esc]  Return to MAIN menu"
350 LOCATE 16,25:COLOR 4:PRINT "SELECT AN OPTION"
360 LOCATE 16,41,0:COLOR 20:PRINT "--->";
370 B$=INPUT$(1):COLOR 7
380 IF B$="B" OR B$="b" THEN KEY ON:CLS:NEW:ON ERROR GOTO 0:END
390 IF B$="D" OR B$="d" THEN CLS:SYSTEM
400 IF B$=CHR$(27) THEN RETURN
410 LOCATE 16,55:COLOR 4:PRINT" CHOOSE [B] [D] OR [Esc]":GOTO 360
420 REM ************************************************************
430 REM              SUBROUTINE TO INPUT DATA
440 REM ************************************************************
450 CLEAR:PRINT"            Input Data For The Prediction of Highway Noise"
460 LOCATE 3,2:PRINT"Name of problem (EG Highway 69 at Highway 17)"
470 LOCATE 4,2:INPUT"              --->",CC$
480 LOCATE 5,2:PRINT"Do you wish to change this title(y/n)"
490 LOCATE 6,2:PRINT"              --->"
500 CCC$=INPUT$(1)
510 LOCATE 6,20:PRINT CCC$
520 IF CCC$="y" OR CCC$="Y" THEN CLS:GOTO 450
530 IF CCC$="n" OR CCC$="N" THEN GOTO 540 ELSE GOTO 500
540 LOCATE 7,2:PRINT"How many roads does this problem have (max of 4)"
550 LOCATE 8,2:PRINT"              --->"
560 C$=INPUT$(1):NR=VAL(C$)
570 IF NR <1 OR NR>4 GOTO 540
580 FOR I=1 TO NR
```

```
590 CLS:LOCATE 2,2:PRINT"Input Data for ---> ";CC$;" Road ";I
600 LOCATE 4,7:PRINT "cars road";I:LOCATE 4,18:INPUT" = ",C(I)
610 LOCATE 4,35:PRINT"speed road";I:LOCATE 4,47:INPUT" = ",S1(I)
620 IF S1(I)<50 OR S1(I)>110 THEN GOTO 690
630 LOCATE 5,1:PRINT"medium tr. road";I:LOCATE 5,18:INPUT" = ",MT(I)
640 LOCATE 5,35:PRINT"speed road";I:LOCATE 5,47:INPUT" = ",S2(I)
650 IF S2(I)<50 OR S2(I)>110 THEN GOTO 700
660 LOCATE 6,2:PRINT"heavy tr. road";I:LOCATE 6,18:INPUT" = ",HT(I)
670 LOCATE 6,35:PRINT"speed road";I:LOCATE 6,47:INPUT" = ",S3(I)
680 IF S3(I)<50 OR S3(I)>110 THEN GOTO 710 ELSE GOTO 740
690 LOCATE 22,4:PRINT"  enter speed of cars between 50 and 110 Km/H":GOTO 610
700 LOCATE 22,4:PRINT"enter speed of Med.Tr between 50 and 110 Km/H":GOTO 640
710 LOCATE 22,4:PRINT"enter speed of Hvy.Tr between 50 and 110 Km/H":GOTO 670
720 LOCATE 22,4:PRINT"enter distance greater than 15 metres        ":GOTO 740
730 LOCATE 22,4:PRINT"enter distance greater than 15 metres        ":GOTO 760
740 LOCATE 7,2:PRINT"dist near lane";I:LOCATE 7,18:INPUT" = ",DN(I)
750 IF DN(I)<15 THEN GOTO 720
760 LOCATE 7,32:PRINT"dist.far lane";I:LOCATE 7,47:INPUT" = ",DF(I)
770 IF DF(I)<15 THEN GOTO 730
780 LOCATE 8,2:PRINT"neg. dist.road";I:LOCATE 8,18:INPUT" = ",X1(I)
790 LOCATE 8,32:PRINT"pos.dist.road";I:LOCATE 8,47:INPUT" = ",X2(I)
800 LOCATE 9,2:PRINT "height of road";I:LOCATE 9,18:INPUT" = ",HH(I)
810 LOCATE 9,31:PRINT"alpha for road";I:LOCATE 9,47:INPUT" = ",AL1(I)
820 IF NLB$=" "  THEN GOTO 850
830 IF NLB$="Y" OR NLB$="y" THEN GOTO 910
840 IF I>1 THEN GOTO 1000
850 LOCATE 10,6,0:PRINT"Is there a barrier in this problem (y/n)"
860 NLB$=INPUT$(1)
870 LOCATE 10,50:PRINT NLB$
880 IF NLB$="n" OR NLB$="N" GOTO 980
890 IF NLB$="y" OR NLB$="Y" THEN GOTO 910
900 LOCATE 10,60:PRINT"**Y OR N**":GOTO 850
910 LOCATE 11,19:PRINT"alpha for barrier and road";I:LOCATE 11,47:INPUT" = ",AL2
(I)
920 IF I>1 THEN GOTO 1000
930 LOCATE 12,11:INPUT"distance to barrier = ",DR
940 LOCATE 13,3:INPUT"ground elevation at barrier = ",GB
950 LOCATE 14,4:INPUT"negetive length of barrier = ",L1
960 LOCATE 14,45:INPUT"positive length = ",L2
970 LOCATE 15,12:INPUT"height of barrier = ",HB
980 LOCATE 16,2:INPUT"ground elevation at receiver = ",GE
990 LOCATE 16,42:INPUT"height of receiver = ",HR
1000 NEXT I:GOTO 70
1010 REM ************************************************************
1020 REM                REVIEW INPUT SUBROUTINE
1030 REM ************************************************************
1040 CLS
1050 LOCATE 10,10,0:COLOR 7:PRINT "Which road do you wish to review ?"
1060 D$=INPUT$(1):I=VAL(D$)
1070 IF I>NR OR I<1 THEN LOCATE 12,5:PRINT"Use a valid road number between 1 and
";NR:GOTO 1050
1080 CLS:PRINT"         Input Data for Problem ";CC$;" Road ";I
1090 PRINT USING"                volume of cars = #####.# /h";C(I)
1100 PRINT USING"                 speed of cars = #####.# Km/h";S1(I)
1110 PRINT USING"      volume of medium trucks = #####.# /h";MT(I)
1120 PRINT USING"       speed of medium trucks = #####.# Km/h";S2(I)
1130 PRINT USING"       volume of heavy trucks = #####.# /h";HT(I)
1140 PRINT USING"        speed of heavy trucks = #####.# Km/h";S3(I)
1150 PRINT USING"        distance to near lane = #####.# m";DN(I)
1160 PRINT USING"         distance to far lane = #####.# m";DF(I)
1170 PRINT USING" negative distance along road = #####.# m";X1(I)
```

```
1180 PRINT USING" positive distance along road - #####.# m";X2(I)
1190 PRINT USING"            elevation of road - #####.# m";HH(I)
1200 PRINT USING"      alpha factor free field -     #.##";AL1(I)
1210 IF NLB$-"N" OR NLB$-"n" AND I-1 THEN GOTO 1300
1220 PRINT USING"    alpha factor with barrier -     #.##";AL2(I)
1230 PRINT USING"          distance to barrier - #####.# m";DR
1240 PRINT USING"  ground elevation at barrier - #####.# m";GB
1250 PRINT USING"   negative length of barrier - #####.# m";L1
1260 PRINT USING"   positive length of barrier - #####.# m";L2
1270 PRINT USING"            height of barrier - #####.# m";HB
1280 PRINT USING"          height of receiver - #####.# m";HR
1290 PRINT USING" ground elevation at receiver - #####.# m";GE
1300 PRINT:PRINT"Change road being reviewed of return to MAIN MENU (C/R)"
1310 E$-INPUT$(1)
1320 IF E$-"C" OR E$-"c" THEN GOTO 1040
1330 IF E$-"R" OR E$-"r" THEN RETURN
1340 PRINT"              **** choose [C] or [R]****":GOTO 1310
1350 REM ************************************************************
1360 REM                    MAIN PROGRAM
1370 REM ************************************************************
1380 LOCATE 25,50,0:COLOR 7:PRINT"Wait Program Running"
1390 FOR I-1 TO NR
1400 V-C(I)+MT(I)+HT(I)
1410 Q-(MT(I)*100)/V:R-(HT(I)*100)/V:P-(C(I)*100)/V
1420 PI-3.14159265#:X-180/PI
1430 DO-SQR(DN(I)*DF(I))
1440 REM ******CALCULATE ANGLES*******
1450 F1-(ATN(X1(I)/DO))*X:F2-(ATN(X2(I)/DO))*X
1460 REM ************************************************************
1470 REM        CALCULATE NOISE BEFORE BARRIER CONSTRUCTION
1480 REM ************************************************************
1490 P1-F1:P2-F2:DE-DO:AL-AL1(I)
1500 GOSUB 4180
1510 FOR J-1 TO 4
1520 LF(I,J)-L(J):NEXT J
1530 IF NLB$-"N" OR NLB$-"n" THEN GOTO 2060
1540 REM ************************************************************
1550 REM       CALCULATE NOISE AFTER BARRIER CONSTRUCTION
1560 REM ************************************************************
1570 HBA-HB+GB:HRA-HR+GE
1580 H(1)-0+HH(I):H(2)-.7+HH(I):H(3)-2.44+HH(I)
1590 D1-DN(I)-DR:D2-DF(I)-DR
1600 DS-SQR(D1*D2):DB-DR+DS
1610 FL-(ATN(L1/DR))*X:FR-(ATN(L2/DR))*X
1620 P1-FL:P2-FR:DE-DB:AL-AL2(I)
1630 GOSUB 4180
1640 FOR J-1 TO 4
1650 LB(I,J)-L(J):NEXT J
1660 REM **********CALCULATE DELTAS OF BARRIERS************
1670 FOR J-1 TO 3
1680 AA-SQR((HBA-H(J))^2+DS^2)
1690 BB-SQR((HBA-HRA)^2+DR^2)
1700 CC-SQR((H(J)-HRA)^2+DE^2)
1710 PD(J)-AA+BB-CC
1720 T(J)-3.21*PD(J):NEXT J
1730 GOSUB 4430
1740 IF NLB$-"B" THEN GOTO 2280
1750 FOR J-1 TO 3
1760 IF T(J)-0 THEN T(J)-.000001
1770 LG-LOG(T(J))/LOG(10)
1780 D1-5+14.4*EXP(-.175*(2-LG)^2.5)
```

```
1790 DO=5.15+14.4*EXP(-.59*(1-LG)^2)
1800 IF NN<1 THEN NN=1
1810 IF NN>6 THEN NN=6
1820 D(J)=DO-(DO-D1)*(FI/90)^NN
1830 IF D(J)>19.5 THEN D(J)=19.5
1840 IF HBA-HRA<(H(J)-HRA)*(DR/DB) THEN D(J)=5-25*T(J)
1850 IF D(J)<0 THEN D(J)=0
1860 NEXT J
1870 FOR J=1 TO 3
1880 LL(I,J)=LB(I,J)-D(J)
1890 AR=AR+10^(LL(I,J)/10):NEXT J
1900 LL(I,4)=10*(LOG(AR))/LOG(10)
1910 IF FI>=89 GOTO 2070
1920 IF FL<=-88 GOTO 1970
1930 P1=F1:P2=FL:AL=AL1(I):DE=DO
1940 GOSUB 4180
1950 FOR J = 1 TO 4
1960 LX(I,J)=L(J):NEXT J
1970 IF FR>=88 GOTO 2020
1980 P1=FR:P2=F2:AL=AL1(I):DE=DO
1990 GOSUB 4180
2000 FOR J=1 TO 4
2010 LY(I,J)=L(J):NEXT J
2020 FOR J=1 TO 4
2030 KKK=10^((LL(I,J))/10)+10^((LX(I,J))/10)+10^((LY(I,J))/10)
2040 LL(I,J)=10*LOG(KKK)/(LOG(10))
2050 NEXT J
2060 NEXT I
2070 FOR J=1 TO 4
2080 RR=0:SS=0
2090 FOR I=1 TO NR
2100 RR=RR+10^((LF(I,J)/10))
2110 SS=SS+10^((LL(I,J)/10))
2120 NEXT I
2130 FF(J)=(10/LOG(10))*LOG(RR)
2140 IF SS>RR THEN SS=RR
2150 YY(J)=(10/LOG(10))*LOG(SS)
2160 II(J)=FF(J)-YY(J)
2170 IF FF(J)<10 THEN FF(J)=0
2180 NEXT J
2190 YYY=0
2200 FOR J=1 TO 3
2210 YYY=YYY+10^((YY(J)/10))
2220 NEXT J
2230 YYF=(10/LOG(10))*LOG(YYY)
2240 II(4)=FF(4)-YYF
2250 REM ************************************************************
2260 REM                  PRINT OUTPUTS TO SCREEN
2270 REM ************************************************************
2280 CLS:LOCATE 2,20:PRINT"Free Field Sound Levels"
2290 LOCATE 4,20:PRINT USING"cars                ##.# dBA";FF(1)
2300 LOCATE 5,20:PRINT USING"medium trucks       ##.# dBA";FF(2)
2310 LOCATE 6,20:PRINT USING"heavy trucks        ##.# dBA";FF(3)
2320 LOCATE 7,14:PRINT"                           "
2330 LOCATE 8,20:PRINT USING"TOTAL               ##.# dBA";FF(4)
2340 IF NLB$="B" THEN GOTO 2380
2350 IF NLB$="N" OR NLB$="n" THEN GOTO 2450
2360 LOCATE 12,15:PRINT"         Insertion Losses"
2370 IF NLB$="Y" OR NLB$="y" THEN GOTO 2390
2380 LOCATE 12,25:COLOR 4:PRINT"***INVALID BARRIER CASE***":NLB$="y":GOTO 2450
2390 LOCATE 14,20:PRINT USING"cars                ##.# dBA";II(1)
```

```
2400 LOCATE 15,20:PRINT USING"medium trucks        ##.# dBA";II(2)
2410 LOCATE 16,20:PRINT USING"heavy trucks         ##.# dBA";II(3)
2420 LOCATE 17,15:PRINT"                                    ____"
2430 LOCATE 18,15:PRINT USING"Net Insertion Loss        ##.# dBA";II(4)
2440 LOCATE 20,9:PRINT USING"Sound Level With Barrier       ##.# dBA";YYF
2450 LOCATE 22,15:COLOR 4:PRINT"Do you want a paper copy (y/n)"
2460 F$=INPUT$(1)
2470 IF F$ ="Y" OR F$="y" THEN GOTO 2530
2480 IF F$ ="N" OR F$="n" THEN RETURN
2490 LOCATE 22,55:PRINT"[Y] or [N]":GOTO 2460
2500 REM ************************************************************
2510 REM                  PAPER COPY SUBROUTINE
2520 REM ************************************************************
2530 CLS:LOCATE 15,20,0:COLOR 7:PRINT"Please wait until printing is over"
2540 REM****Setting printer***
2550 LPRINT CHR$(27);"(s12h"
2560 LPRINT CHR$(27);"&a6L"
2570 LPRINT CHR$(27);"&a85M"
2580 LPRINT CHR$(27);"&l06E"
2590 LPRINT"      Problem Title : ";CC$
2600 FOR I=1 TO NR
2610 LPRINT:LPRINT"                    Input Data for Road";I:LPRINT
2620 LPRINT USING"                volume of cars - #####.# /h";C(I)
2630 LPRINT USING"                 speed of cars - #####.# Km/h";S1(I)
2640 LPRINT USING"      volume of medium trucks - #####.# /h";MT(I)
2650 LPRINT USING"       speed of medium trucks - #####.# Km/h";S2(I)
2660 LPRINT USING"       volume of heavy trucks - #####.# /h";HT(I)
2670 LPRINT USING"        speed of heavy trucks - #####.# Km/h";S3(I)
2680 LPRINT USING"        distance to near lane - #####.# m";DN(I)
2690 LPRINT USING"         distance to far lane - #####.# m";DF(I)
2700 LPRINT USING" negative distance along road - #####.# m";X1(I)
2710 LPRINT USING" positive distance along road - #####.# m";X2(I)
2720 LPRINT USING"            elevation of road - #####.# m";HH(I)
2730 LPRINT USING"      alpha factor free field -     #.##";AL1(I)
2740 IF NLB$="N" OR NLB$="n" AND I=1 THEN GOTO 2840
2750 IF NLB$="Y" OR NLB$="y" AND I=1 THEN GOTO 2770
2760 IF NLB$="N" OR NLB$="n" AND I>1 THEN GOTO 2860
2770 LPRINT USING"    alpha factor with barrier -     #.##";AL2(I)
2780 IF I>1 THEN GOTO 2860
2790 LPRINT USING"          distance to barrier - #####.# m";DR
2800 LPRINT USING"  ground elevation at barrier - #####.# m";GB
2810 LPRINT USING"   negative length of barrier - #####.# m";L1
2820 LPRINT USING"   positive length of barrier - #####.# m";L2
2830 LPRINT USING"           height of barrier - #####.# m";HB
2840 LPRINT USING"         height of receiver - #####.# m";HR
2850 LPRINT USING" ground elevation at receiver - #####.# m";GE
2860 NEXT I
2870 LPRINT:LPRINT"                    Free Field Sound Levels"
2880 LPRINT USING"               cars                 ##.# dBA";FF(1)
2890 LPRINT USING"               medium trucks        ##.# dBA";FF(2)
2900 LPRINT USING"               heavy trucks         ##.# dBA";FF(3)
2910 LPRINT"                                        ____"
2920 LPRINT USING"               Total                ##.# dBA";FF(4)
2930 IF NLB$="N" OR NLB$="n" THEN RETURN
2940 IF NLB$="B" THEN GOTO 2970
2950 LPRINT:LPRINT"                        Insertion Losses"
2960 IF NLB$="Y" OR NLB$="y" THEN GOTO 2980
2970 LPRINT:LPRINT"          ****Invalid Barrier Case****":RETURN
2980 LPRINT USING"               cars                 ##.# dBA";II(1)
2990 LPRINT USING"               medium trucks        ##.# dBA";II(2)
3000 LPRINT USING"               heavy trucks         ##.# dBA";II(3)
```

```
3010 LPRINT"                                          ___"
3020 LPRINT USING"              Net Insertion Loss   ##.# dBA";II(4)
3030 LPRINT:LPRINT USING"         Sound Level With Barrier  ##.# dBA";YYF
3040 LPRINT CHR$(12)
3050 RETURN
3060 REM ************************************************************
3070 REM           SUBROUTINE TO EDIT EXISTING DATA
3080 REM ************************************************************
3090 CLS
3100 LOCATE 10,2,0:PRINT"Which road do you wish to edit between 1 and ";NR
3110 G$=INPUT$(1):I=VAL(G$)
3120 IF I=0 OR I>NR THEN LOCATE 12,2:PRINT"only use an existing road":GOTO 3100
3130 CLS:LOCATE 2,17:PRINT"Edit variables for road";I
3140 LOCATE 3,10:PRINT"[1] Problem Title"
3150 LOCATE 4,10:PRINT"[2] VOLUME: Cars                [3] SPEED: Cars"
3160 LOCATE 5,10:PRINT"[4]       : Medium Trucks       [5]       : Medium Trucks"
3170 LOCATE 6,10:PRINT"[6]       : Heavy Trucks        [7]       : Heavy Trucks"
3180 LOCATE 7,10:PRINT"[8] DISTANCE: Near Lane         [9] DISTANCE: Far Lane"
3190 LOCATE 8,9:PRINT"[10] Neg. Dist.Along Road       [11] Pos. Distance"
3200 LOCATE 9,9:PRINT"[12] Elevation of Road          [13] Alpha: Free Field"
3210 IF NLB$ -"N" OR NLB$-"n"  THEN GOTO 3290
3220 LOCATE 10,9:PRINT"[14] Alpha With Barrier"
3230 LOCATE 11,9:PRINT"[15] Dist. to Barrier           [16] Ground El.at Barrier"
3240 LOCATE 12,9:PRINT"[17] Neg. Length of Barrier     [18] Pos. Length"
3250 LOCATE 13,9:PRINT"[19] Height: Barrier"
3260 LOCATE 14,9:PRINT"[20]       : Reciever           [21] Ground El.:Reciever"
3270 LOCATE 15,19:PRINT"[22] Change Road Being Edited"
3280 LOCATE 17,9:INPUT"[1-22] OR [23] to Return to MAIN MENU--->",CNGE:GOTO 3320
3290 LOCATE 10,9:PRINT"[14] Height: Reciever           [15] Ground El.:Reciever"
3300 LOCATE 11,19:PRINT"[15] CHANGE ROAD BEING EDITED"
3310 LOCATE 13,9:INPUT"[0-15] OR [16] TO RETURN TO MAIN MENU--->",CNGE:GOTO 3330
3320 CLS:ON CNGE GOTO 3340,3360,3380,3400,3420,3440,3470,3480,3500,3520,3540,356
0,3580,3600,3620,3640,3660,3680,3700,3720,3740,3090,70:GOTO 3130
3330 CLS:ON CNGE GOTO 3340,3360,3380,3400,3420,3440,3470,3480,3500,3520,3540,356
0,3580,3720,3740,3090,70:GOTO 3130
3340 PRINT"              The current problem title is ";CC$
3350 INPUT"              The new problem title is --->";CC$:GOTO 3130
3360 PRINT"             The current volume of cars is ";C(I)
3370 INPUT"                       Enter new volume--->";C(I):GOTO 3130
3380 PRINT"             The current speed for cars is ";S1(I)
3390 INPUT"                        Enter new speed--->";S1(I):GOTO 3130
3400 PRINT"    The current volume of medium trucks is ";MT(I)
3410 INPUT"                       Enter new volume--->";MT(I):GOTO 3130
3420 PRINT"     The current speed of medium trucks is ";S2(I)
3430 INPUT"                        Enter new speed--->";S2(I):GOTO 3130
3440 PRINT"     The current volume of heavy trucks is ";HT(I)
3450 INPUT"                       Enter new volume--->";HT(I):GOTO 3130
3460 PRINT"      The current speed of heavy trucks is ";S3(I)
3470 INPUT"                        Enter new speed--->";S3(I):GOTO 3130
3480 PRINT"          The distance to the near lane is ";DN(I)
3490 INPUT"                Enter the new distance--->";DN(I):GOTO 3130
3500 PRINT"           The distance to the far lane is ";DF(I)
3510 INPUT"                Enter the new distance--->";DF(I):GOTO 3130
3520 PRINT"   The negative distance along the road is ";X1(I)
3530 INPUT"                Enter the new distance--->";X1(I):GOTO 3130
3540 PRINT"   The positive distance along the road is ";X2(I)
3550 INPUT"                Enter the new distance--->";X2(I):GOTO 3130
3560 PRINT"             The elevation of the road is ";HH(I)
3570 INPUT"               Enter the new elevation--->";HH(I):GOTO 3130
3580 PRINT"              The current alpha factor is ";AL1(I)
3590 INPUT"             Enter the new alpha factor--->";AL1(I):GOTO 3130
```

```
3600 PRINT"    The alpha factor with noise barrier is ";AL2(I)
3610 INPUT"             Enter the new alpha factor--->";AL2(I):GOTO 3130
3620 PRINT"           The distance to the barrier is ";DR
3630 INPUT"                Enter the new distance--->";DR:GOTO 3130
3640 PRINT"    The ground elevation at the barrier is ";GB
3650 INPUT"               Enter the new elevation--->";GB:GOTO 3130
3660 PRINT"     The negative length to the barrier is ";L1
3670 INPUT"                    Enter the new length--->";L1:GOTO 3130
3680 PRINT"     The positive length of the barrier is ";L2
3690 INPUT"                    Enter the new length--->";L2:GOTO 3130
3700 PRINT"             The height of the barrier is ";HB
3710 INPUT"                    Enter the new height--->";HB:GOTO 3130
3720 PRINT"           The height of the receiver is ";HR
3730 INPUT"                    Enter the new height--->";HR:GOTO 3130
3740 PRINT"   The ground elevation at the receiver is ";GE
3750 INPUT"                  Enter the new elevation--->";GE:GOTO 3130
3760 REM ************************************************************
3770 REM          SUBROUTINE TO SAVE AND LOAD DATA
3780 REM ************************************************************
3790 CLS:DISK$-"0":DIR$-"0":TFILE$-"0"
3800 LOCATE 1,10:PRINT"Disk Drive":LOCATE 1,20,0:PRINT"--->"
3810 DISK$-INPUT$(1)
3820 IF DISK$-"a" OR DISK$-"A" OR DISK$-"b" OR DISK$-"B" OR DISK$-"c" OR DISK$-"
C" THEN GOTO 3830 ELSE GOTO 3800
3830 LOCATE 1,20:PRINT"--->";DISK$
3840 DISK$-DISK$+":"
3850 LOCATE 1,39:INPUT "Directory then 'Enter'--->",DIR$
3860 LOCATE 1,65:PRINT DIR$
3870 IF DIR$-" " THEN DIR$-"\" ELSE DIR$-"\"+DIR$
3880 IF DIR$-"\" THEN TFILE$-DISK$+DIR$+"d9999" ELSE TFILE$-DISK$+DIR$+"\d9999"
3890 ON ERROR GOTO 4580
3900 IF DISK$-"A:" OR DISK$-"a:" THEN OPEN TFILE$ FOR INPUT AS #1
3910 IF DISK$- "B:" OR DISK$-"b:" THEN OPEN TFILE$ FOR INPUT AS #1
3920 TFILE$ - " "
3930 CLOSE #1
3940 SHELL DISK$:SHELL "CD"+DIR$
3950 LOCATE 1,1:PRINT"                                    "
3960 SHELL"DIR *.DAT/P"
3970 LOCATE 2,1:
3980 IF IN1-1 THEN LOCATE 2,1:PRINT"                                        Loa
d Data From                  .Dat"
3990 IF IN1-6 THEN PRINT "                                          Save Data I
n                .Dat"
4000 LOCATE 2,57: INPUT "File--->",ANAME$
4010 ANAME$-LEFT$(ANAME$,8)+".DAT"
4020 IF IN1-1 THEN GOTO 4080
4030 OPEN"O",#1,ANAME$
4040 FOR I-1 TO NR
4050 WRITE #1,CC$,NR,C(I),S1(I),MT(I),S2(I),HT(I),S3(I),DN(I),DF(I),X1(I),X2(I),
HH(I),AL1(I),NLB$,AL2(I),DR,GB,L1,L2,HB,GE,HR
4060 NEXT I
4070 CLOSE #1:RETURN
4080 OPEN"I",#1,ANAME$
4090 ON ERROR GOTO 4580
4100 FOR I-1 TO 4
4110 INPUT #1,CC$,NR,C(I),S1(I),MT(I),S2(I),HT(I),S3(I),DN(I),DF(I),X1(I),X2(I),
HH(I),AL1(I),NLB$,AL2(I),DR,GB,L1,L2,HB,GE,HR
4120 IF EOF(1) THEN GOTO 4140
4130 NEXT I
4140 CLOSE #1:RETURN
4150 REM ************************************************************
```

```
4160 REM                  NOISE SUBROUTINE
4170 REM ***********************************************************
4180 IF AL=0 THEN PH=P2-P1:GOTO 4300
4190 IF AL=1 THEN PH=(SIN(P2/X)-SIN(P1/X))*X:GOTO 4300
4200 N=1/(.134*AL+.225)
4210 M=(90)*(.58*AL^.9)/(.58*AL^.9+1)
4220 Y1=ABS(P1):Y2 = ABS(P2)
4230 IF P1=0 GOTO 4250
4240 PA=P1*(1-(M/Y1)*(Y1/90)^N)
4250 IF P2=0 GOTO 4270
4260 PB=P2*(1-(M/Y2)*(Y2/90)^N)
4270 IF P1=0 THEN PA=0
4280 IF P2=0 THEN PB=0
4290 PH=PB-PA
4300 K(1)=(P/44253#)*S1(I)^2.81
4310 K(2)=(Q/583.36)*S2(I)^2.39
4320 K(3)=.27801*R*S3(I)^1.46
4330 K(4)=K(1)+K(2)+K(3)
4340 FOR J=1 TO 4
4350 IF K(J)=0 THEN L(J)=0 :GOTO 4380
4360 IF PH<.001 THEN L(J)=0:GOTO 4380
4370 L(J)=(10/LOG(10))*LOG((PH/15)*V*K(J)*(15/DE)^(1+AL))
4380 NEXT J
4390 RETURN
4400 REM***********************************************************
4410 REM SUBROUTINE TO DECIDE ON FI
4420 REM***********************************************************
4430 QQ=.25
4440 IF FR<-10 THEN GOTO 4490
4450 IF FL>10 THEN GOTO 4490
4460 IF ABS(FR+FL)<=50 THEN GOTO 4500
4470 IF ABS(FR)>ABS(FL) THEN GOTO 4520
4480 IF ABS(FR)<ABS(FL) THEN GOTO 4540
4490 NLB$="B":RETURN
4500 NN=1+(1.25+T(J)/2)*(1-3.24*(ABS(FR+FL)/90)^2
4510 FI=(FR-FL)/2:RETURN
4520 FI=FR+QQ*FL
4530 NN=2+T(J)/2:RETURN
4540 FI=-QQ*FR-FL:NN=2+T(J)/2:RETURN
4550 REM***********************************************************
4560 REM ERROR TRAPS
4570 REM***********************************************************
4580 IF ERR=71 THEN LOCATE 2,1:PRINT"Disk Drive Not Ready **INSERT DATA DISK**":
LOCATE 2,45:PRINT "and Press any key to continue      ";:INT71$=INPUT$(1):RESUME
 NEXT
4590 IF ERR=76 THEN LOCATE 2,10:PRINT"**Path Not Found**":LOCATE 2,39:PRINT "Pre
ss any key to continue   ";:INT76$=INPUT$(1):RESUME 3790
4600 IF ERR=53 AND TFILE$ <> " " THEN RESUME NEXT
4610 IF ERR=53 THEN LOCATE 2,10:PRINT"**File Not Found**":LOCATE 2,39:PRINT "Pre
ss any key to continue   ";:INT53$=INPUT$(1):RESUME 3980
4620 RESUME NEXT
4630 REM***********************************************************
4640 REM SUBROUTINE FOR ADDING DECIBELS TOGETHER
4650 REM***********************************************************
4660 CLS:LOC1=3:SLL=0:SSLL=0
4670 LOCATE LOC1,2:INPUT"Number of sound levels to add together ? ",NROAD
4680 LOC1=LOC1+1:IF NROAD <1 GOTO 4660
4690 FOR I=1 TO NROAD
4700 LOC1=LOC1+1
4710 LOCATE LOC1,28:PRINT "Sound Level";I:LOCATE LOC1,41:INPUT " = ", SL(I)
4720 SSL=SSL+10^((SL(I)/10))
```

```
4730 NEXT I
4740 SSLL=(10/LOG(10))*LOG(SSL):LOC1=LOC1+2
4750 LOCATE LOC1,24:PRINT USING "TOTAL SOUND LEVEL = ##.#";SSLL
4760 LOCATE 23,15:PRINT"press any key to return to MAIN MENU"
4770 T$=INPUT$(1):RETURN
```

Input Terms

C(I) = Volume of cars on road I.

S1(I) = Speed of cars on road I in km/h.

MT(I) = Volume of medium trucks on road I.

S2(I) = Speed of medium trucks on road I in km/h.

HT(I) = Volume of heavy trucks on road I.

S3(I) = Speed of heavy trucks on road I in km/h.

DN(I) = Distance to the centre of near lane on road I in metres.

DF(I) = Distance to the centre of far lane on road I in metres.

X1(I) = Length of visible roadway, in metres, to the left of the perpendicular receiver line, must be a negative value when measured to the left of that line. (Exception: skew to the right).

X2(I) = Length of visible roadway, in metres, to the right of the perpendicular receiver line, must be a positive value when measured to the right of the line. (Exception: skew to the left).

HH(I) = Height of road I in metres.

AL1(I) = Ground cover coefficient α in free field.

AL2(I) = Ground cover coefficient α with barrier in place.

DR = Distance to barrier from receiver in metres.

GB = Ground elevation at barrier in metres.

L1 = Length of the barrier left of the perpendicular receiver line, must be negative when measured to the left of that line; in metres.

L2 = Length of the barrier right of the perpendicular receiver line, must be positive when measured to the right of that line, in metres.

HB = Height of barrier in metres.

GE = Ground elevation of receiver in metres.

HR = Height of receiver in metres.

Calculated Terms

V = Hourly volume of total traffic, number of vehicles (cars and trucks) per hour.

P = Percentage of automobiles or cars and small trucks.

Q = Percentage of medium trucks.

R = Percentage of heavy trucks.

DO = Equivalent lane distance, in metres, for free field condition.

F1, F2 = Subtending angles calculated from X1 and X2.

DE = Equivalent lane distance in metres.

LF(J) = Noise level, in dBA, for freefield, before barrier.

HBA = Barrier height and ground elevation at barrier.

HRA = Receiver height and ground elevation at receiver.

H(1) = Source height in metres for cars.

H(2) = Source height in metres for medium trucks.

H(3) = Source height in metres for heavy trucks.

DS = Equivalent distance between barrier and road.

DB = Distance to barrier from receiver plus DS.

FL = Modified subtending angle, in degrees, to the left of the segment; (ϕ_1').

FR = Modified subtending angle, in degrees, to the left of the segment (ϕ_2').

PH = PB-PA, = $\bar{\phi}$.

LB(I,J) = Noise level, in dBA, for barrier field or segment.

LL(I,J) = Noise level, in dBA, after barrier construction.

PD(J) = Path length differences, in metres.

T(J) = Fresnel number (N_0).

D(J) = Noise attenuation (Δ), basic values, in dBA.

FI, FF = Entrance angle, in degrees, for modifying the noise attenuation value, D(J).

LX(I,J) = Leakage of noise left of the barrier, in dBA.

LY(I,J) = Leakage of noise right of the barrier, in dBA.

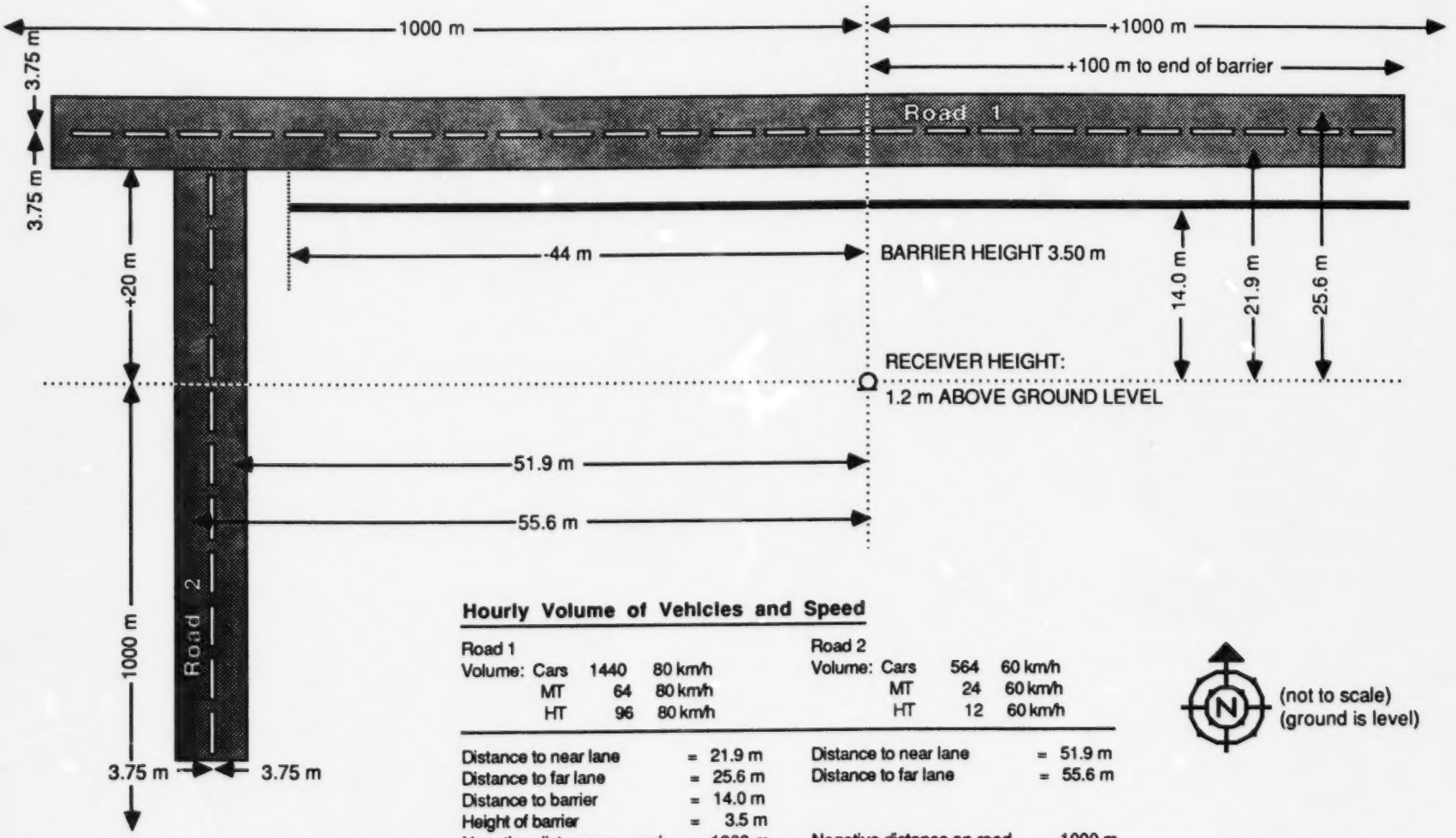
LL(J) = Net insertion loss, in dBA, for one roadway.

FF(J) = Free field noise level, in dBA, from I roadways.

YY(J) = Noise level after barrier installation, from I roadways.

II(J) = Final net insertion loss for I roadways.

YYF = Sound level with barrier.



Hourly Volume of Vehicles and Speed

Road 1			Road 2		
Volume: Cars	1440	80 km/h	Volume: Cars	564	60 km/h
MT	64	80 km/h	MT	24	60 km/h
HT	96	80 km/h	HT	12	60 km/h

Distance to near lane	= 21.9 m	Distance to near lane	= 51.9 m
Distance to far lane	= 25.6 m	Distance to far lane	= 55.6 m
Distance to barrier	= 14.0 m		
Height of barrier	= 3.5 m		
Negative distance on road	= -1000 m	Negative distance on road	= -1000 m
Positive distance on road	= 1000 m	Positive distance on road	= 20 m
Alpha free field	= 0.5	Alpha free field	= 0.5
Negative distance on barrier	= - 44 m		
Positive distance on barrier	= 100 m		
Alpha with barrier present	= 0.0		

(not to scale)
(ground is level)

Figure C1/ Input Data — Sketch

Problem Title : Input for Figure C1

Input Data for Road 1

volume of cars	=	1440.0 /h
speed of cars	=	80.0 Km/h
volume of medium trucks	=	64.0 /h
speed of medium trucks	=	80.0 Km/h
volume of heavy trucks	=	96.0 /h
speed of heavy trucks	=	80.0 Km/h
distance to near lane	=	21.9 m
distance to far lane	=	25.6 m
negative distance along road	=	-1000.0 m
positive distance along road	=	1000.0 m
elevation of road	=	0.0 m
alpha factor free field	=	0.50
alpha factor with barrier	=	0.00
distance to barrier	=	14.0 m
ground elevation at barrier	=	0.0 m
negative length of barrier	=	-44.0 m
positive length of barrier	=	100.0 m
height of barrier	=	3.5 m
height of receiver	=	1.2 m
ground elevation at receiver	=	0.0 m

Free Field Sound Levels

cars	65.2 dBA
medium trucks	62.5 dBA
heavy trucks	68.7 dBA
Total	71.0 dBA

Insertion Losses

cars	9.2 dBA
medium trucks	8.7 dBA
heavy trucks	6.7 dBA
Net Insertion Loss	7.5 dBA

Sound Level With Barrier 63.4 dBA

Problem Title : Input for Figure C1

Input Data for Road 2

volume of cars =	564.0	/h
speed of cars =	60.0	Km/h
volume of medium trucks =	24.0	/h
speed of medium trucks =	60.0	Km/h
volume of heavy trucks =	12.0	/h
speed of heavy trucks =	60.0	Km/h
distance to near lane =	51.9	m
distance to far lane =	55.6	m
negative distance along road =	-1000.0	m
positive distance along road =	20.0	m
elevation of road =	0.0	m
alpha factor free field =	0.50	
height of receiver =	1.2	m
ground elevation at receiver =	0.0	m

Free Field Sound Levels

cars	50.4 dBA
medium trucks	48.0 dBA
heavy trucks	50.6 dBA
Total	54.6 dBA

Problem Results

To properly calculate the answer to the problem presented in Figure C1, the acoustical energies from the two roads must be combined properly.

Sound Level (No Barrier)

Road 1 = 71.0 dBA
Road 2 = 54.6 dBA

$\therefore$ Total = $10 \cdot \log_{10}[10^{7.10} + 10^{5.46}]$
= 71.1 dBA

Sound Level (With Barrier)

Road 1 = 63.4 dBA
Road 2 = 54.6 dBA

$\therefore$ Total = $10 \cdot \log_{10}[10^{6.34} + 10^{5.46}]$
= 63.9 dBA

Appendix D/

Example and User Guide

APPENDIX D/ EXAMPLE AND USER GUIDE

To provide an example and user's guide to using the (low level) "BASIC" program, a problem is chosen that is in manual form in Reference 1 (FHWA-RD-77-108), Problem, 10, Page 39, up to Table 4 on Page 53.

The following values are given:

Traffic Data: Average Speed of all vehicles: 75 km/h, in all lanes. Vehicles per hour (different for east- and westbound lanes), different for east-and westbound lanes:

Automobiles/Cars:	EB: 317	WB: 281
Medium Trucks	EB: 24	WB: 12
Heavy Trucks	EB: 22	WB: 25
	$\sum$EB = 363	$\sum$WB = 318

These data lead to the following input values:

Eastbound (EB), first roadway:

$V = 363$ vehicles/h $\quad S_1 = S_2 = S_3 = 75$ km/h

$$Q = \frac{24 \times 100}{363} = 6.612\% \quad R = \frac{22 \times 100}{363} = 6.061\%$$

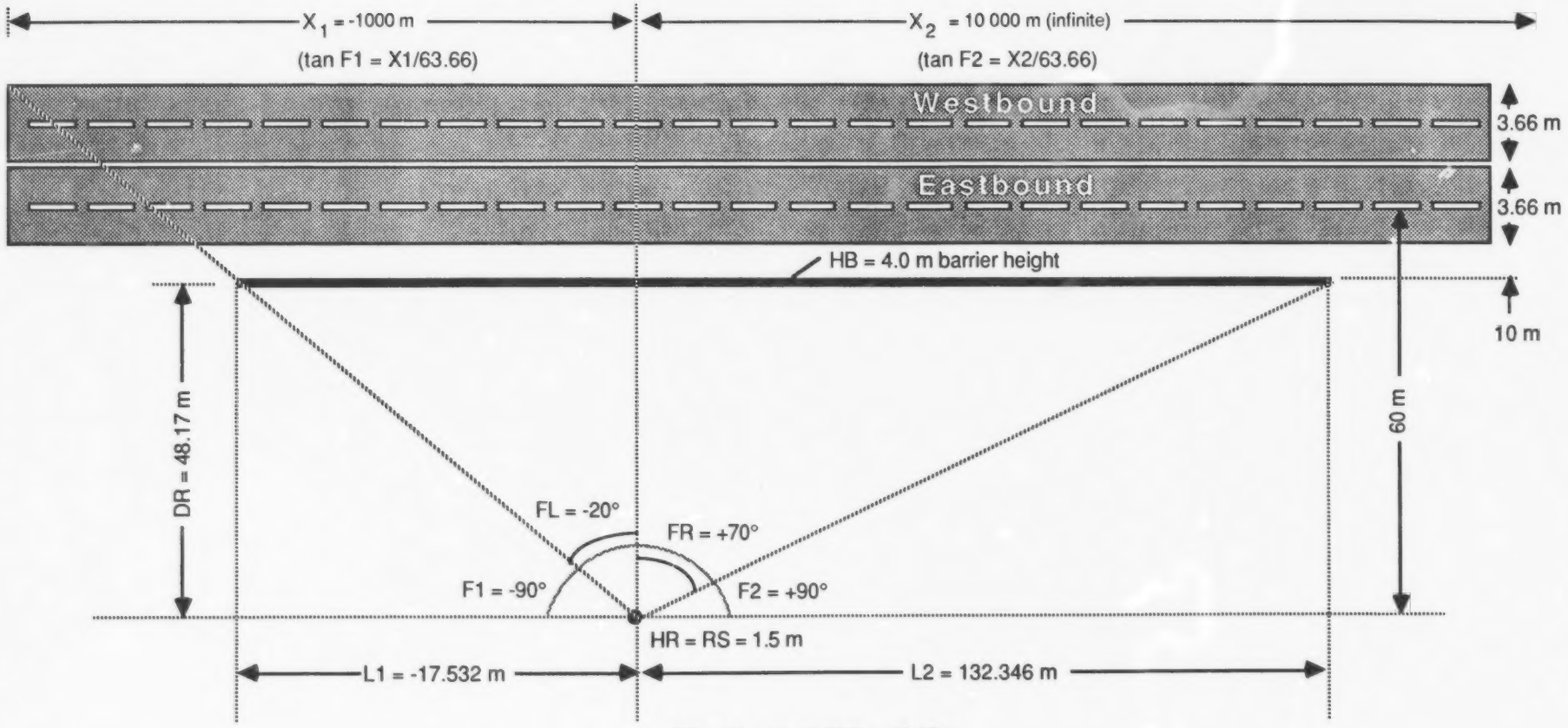
Westbound (WB), second roadway:

$V = 318$ vehicles/h $\quad S_1 = S_2 = S_3 = 75$ km/h

$$Q = \frac{12 \times 100}{318} = 3.774\% \quad R = \frac{25 \times 100}{318} = 7.862\%$$

Note: the program will also accept different speeds for the three classes of vehicles and for the two roadways or lanes.

In this example the two lanes, EB and WB, are treated as two different roadways because of the difference in traffic volumes. If volumes (and speeds) were identical, the two lanes could be combined on a roadway with different values of DF and DN.



DR = 60 - 10 - 3.66/2 = 48.17 m
L1 = -48.17 x tan 20° = 17.532 m
L2 = +48.17 x tan 70° = 132.346 m

Free field ground absorption: α_F = AF = 0.5

Figure D1/ Geometric Data
(Not to scale)

Geometric Data

A ground cover covefficient is chosen pertaining to "absorptive", $\alpha_F = 0.5$. Figure D-1 lays out the geometric data of the example.

For each of the two roadways, eastbound and westbound, the following values must be obtained from drawings, maps, etc. (refer to Figure D1).

Value	Eastbound	Westbound
Left length of roadway, X1 = (negative)	- 10 000 m	- 10 000 m
Left length of barrier, L1 = (negative)	- 17.532 m	(- 17.532 m)
Right length of roadway, X2 = (positive)	- 10 000 m	10 000 m
Right length of barrier, L2 = (positive)	132.346 m	(132.346 m)
Near lane distance DN =	60 m	63.66 m
Far Lane distance DF =	60 m	63.66 m

Notes: 1. As there is only one lane per roadway, DN = DF.

2. 10 000 and -10 000 m stand for a practically infinite length of roadway.

Value	Eastbound	Westbound
Receiver distance from barrier, DR =	48.17 m	(48.17 m)
Barrier height above roadway BH =	4.0 m	(4.0 m)
Receiver height above roadway HR =	1.5 m	(1.5 m)
Receiver height above ground level RS =	1.5 m	(1.5 m)

Note: Values in parentheses need not be repeated as they remain the same for both westbound and eastbound lanes.

Input data are listed at the end of the program, using a convenient bulk input:

```
3000  REM
3010  REM   V,      Q,        R,        S1,    S2,    S3
3020  DATA  363,     6.612,    6.061,    75,    75,    75
3030  REM                                                      (EASTBOUND)
3040  REM   NR,      X1,       X2,       DN,    DF,    AF
3050  DATA  2,       -10000,   10000,    60,    60,    .50
3060  REM
3070  REM   HB,      L1,       L2,             DR,    HR,    RS  (EB & WB)
3080  DATA  4.0,     -17.532,  132.346,        48,17, 1.5,   1.5
3090  REM
3100  REM
3110  REM   V,       Q,        R,        S1     S2,    S3
3120  DATA  318,     3.774,    7.862,    75,    75,    75      (WESTBOUND)
3130  REM
3140  REM   X1,      X2,       DN,       DF,    AF
3150  DATA  -10000,  10000,    63.66,    63.66, .5
3160  REM
```

Example Output

FREE FIELD NOISE LEVEL AND DELTA VALUES (EB)

CARS:	51.822	15.157
MEDIUM TRUCKS:	51.538	13.878
HEAVY TRUCKS:	55.822	9.649
TOTAL, ALL VEHICLE:	58.304	

NOISE AFTER BARRIER AND NET INSERTION LOSS, ALPHAB = 0

CARS:	48.360	3.461
MEDIUM TRUCKS:	48.204	3.331
HEAVY TRUCKS:	53.249	2.574
TOTAL, ALL VEHICLE:	55.391	2.913

FREE FIELD NOISE LEVEL AND DELTA VALUES (WB)

CARS:	50.912	14.210
MEDIUM TRUCKS:	48.142	12.979
HEAVY TRUCKS:	55.991	9.171
TOTAL, ALL VEHICLE:	57.678	

NOISE AFTER BARRIER AND NET INSERTION LOSS, ALPHAB = 0

CARS:	47.557	3.355
MEDIUM TRUCKS:	44.943	3.200
HEAVY TRUCKS:	53.582	2.409
TOTAL, ALL VEHICLE:	55.002	2.677

TOTAL NOISE BEFORE AND AFTER BARRIER, AND NET INSERTION LOSS

NUMBER	BEFORE	AFTER	INSERTION LOSS
1 CAR	54.401	50.988	3.413
2 MEDIUM TRUCK	53.174	49.885	3.290
3 HEAVY TRUCKS	58.918	56.429	2.489
4 TOTAL	61.013	58.211	2.802

	L_{eq} (BEFORE)	L_{eq} (AFTER)	I (FOR BOTH, EB & WB)

COMPARISON OF THE TOTAL WITH REFERENCE 1, TABLE 4

BEFORE	AFTER	NET INSERTION LOSS
61.1	58.2	2.9